NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

July 1, 2014

Video Study

NTSB Case Number:
DCA13MA121

A. ACCIDENT

Location:	Soldotna, Alaska
Date:	July 7, 2013
Time:	1120 Alaska Daylight Time
Airplane:	de Havilland DHC-3T Turbo Otter

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

On July 7, 2013, about 1120 Alaska daylight time, a DeHavilland DHC-3T “Otter” airplane, N93PC, was destroyed after a collision with terrain shortly after takeoff from the Soldotna Airport, Soldotna, Alaska. The airplane was registered to Rediske Family Limited Partnership, Nikiski, Alaska, and was operated by Rediske Air, Inc. under the provisions of 14 CFR Part 135, as an on-demand charter flight. The commercial pilot and nine passengers were fatally injured. Visual meteorological conditions prevailed and no flight plan was filed for the flight destined to Bear Mountain Lodge, approximately 90 miles southwest of Soldotna.

D. DETAILS OF INVESTIGATION

The goal of this study was to estimate the trajectory and speed of the DHC-3T airplane based on information in a video recorded on an iPhone 5 camera. The camera was hand-held by a passenger on the airplane who recorded the scene south of the runway through the fourth window on the left side of the airplane. The video included the taxiing, takeoff roll, takeoff and flight phases. The useful segment of the video ended when, shortly after takeoff, the airborne airplane rolled to the right and started losing altitude. After that time, the video no longer showed any ground reference features, making the estimation of its location and orientation impossible.

The analysis of this video posed unique challenges because the camera was hand-held as opposed to being fixed to the airplane. Consequently, it became necessary to first estimate the time-varying orientation of the camera with respect to the airplane and then, with the camera fixed to the airplane with that orientation, to estimate the location and orientation of the airplane with respect to the ground.

Estimating Camera Orientation and Location

The camera was hand-held by a passenger seated near the fourth window on the left side of the airplane. The camera was pointed to the left and, being hand-held, its orientation with respect to the window was not constant. The yaw, pitch and roll angles of the camera varied by up to 10 degrees during the analyzed video segment. Such large angular deviations of camera angles translate to very large errors when used for airplane location and orientation estimation that is based on ground reference points that are located far from the airplane. Consequently, it was necessary to accurately estimate the time-varying orientation of the camera with respect to the airplane.

A typical frame from the video is shown in Figure 1. It shows the bottom of the window, the left wing, and the left wing support. Using measurements of a DHC-3T airplane and photographs, a 3D model of this visible part of the airplane was developed. It consisted of points along the bottom of the window, along the leading edge and the tip of the left wing, and points along the top and bottom of the left wing support. These points were specified in 3D in a coordinate system fixed to the airplane.

The estimation of the location and orientation of the camera with respect to the airplane was based on aligning a synthesized video frame with an actual video frame using a model of the camera optics. The camera optics model was developed by measuring the horizontal field of view (HFOV) of the iPhone 5 video camera. A computer model that used the measured HFOV and the known 1080x1920 image resolution was then used to generate synthesized image frames where the points from the 3D airplane model were mapped onto a 1080x1920 frame from the iPhone video. This mapping depended on the location and orientation of the camera with respect to the 3D airplane model.

An interactive process was then used where simulated camera location and orientation were varied until all the mapped points from the 3D airplane model were aligned with their images in the actual video frames. Figure 2a shows one video frame after alignment. Once alignment was achieved, the location and orientation of the simulated camera had to be the location and orientation of the actual iPhone camera when that frame was acquired. This process estimated the orientations and locations of the actual camera for the video frames that were analyzed. The estimated locations of the camera were by-products of the estimated orientations. They were of no further use because the location fluctuations with respect to the airplane were negligible compared to the distance of the airplane from ground reference points that were used to estimate its location and orientation.

Estimating Airplane Location and Orientation

Airplane locations and orientations corresponding to frames from the video were estimated by aligning ground reference points mapped onto frames from the iPhone video with the images of these points in the video frames. This process was similar to the estimation of the location and orientation of the camera with respect to the airplane. However, during this analysis, the camera was fixed to the airplane and oriented with respect to it according to the previously estimated camera yaw, pitch and roll angles.

Figure 1 shows some of the ground features that were used for estimating the location and orientation of the airplane. They included the paved road, the fence, the power lines, and the runway that was visible before takeoff. Points along these features were useful for accurate estimation of altitude, pitch angle and roll angle of the airplane. Fence poles, signs on the fence, power line poles, and several trees located just behind the fence were useful for accurate estimating the location of the airplane along its flight path.

The locations of the reference points were derived from survey of the accident site and from Google Earth images of it. They were specified in 3D in an earth-fixed coordinate system.

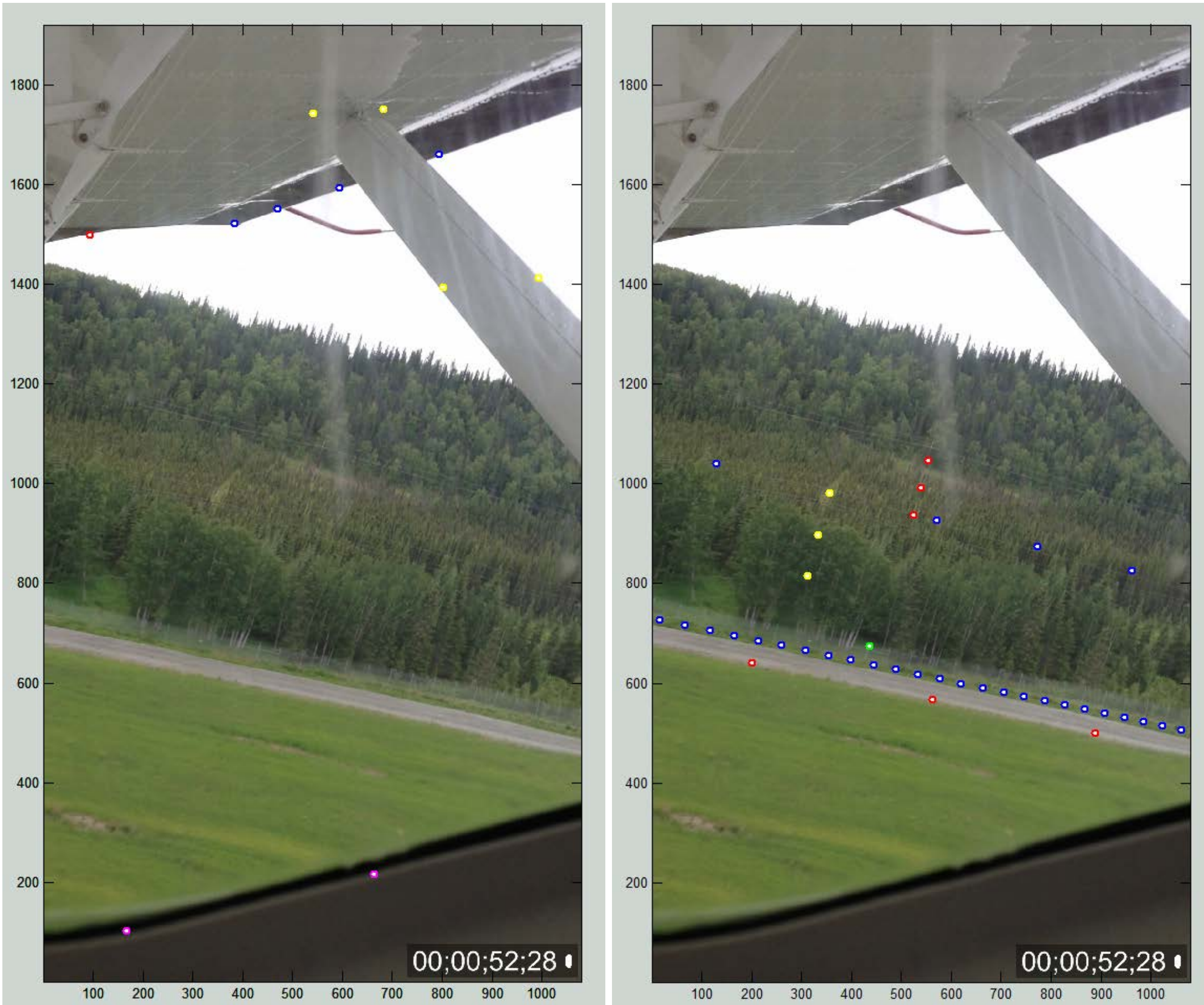
Figure 2b shows one video frame after mapped ground reference points were aligned with their images in the frame. When accurate alignment was achieved, the location and orientation of the airplane had to be the location and orientation of the actual airplane when that frame was acquired. During the interactive estimation of airplane location and orientation, the camera was oriented relative to the airplane according to the angles estimated above. The orientation of the camera relative to the airplane was different for each analyzed video frame.

Estimating Airplane Trajectory and Speed

The location and orientation of the airplane was estimated at ten times during takeoff roll and at fifteen times during its flight, each corresponding to a frame from the video. The first estimated location was shortly after takeoff roll started and the last one was just before the video no longer showed ground reference points.

The time when each video frame was acquired was known. iPhone 5 has variable frame rate that can change from 24 fps to 30 fps and back while a video is being recorded. Frames from the video were extracted at the rate of 30 fps, i.e., the spacing between extracted frames was 1/30 seconds even if the video had some segments recorded at 24 fps. Therefore, it was possible to assign accurate time to each frame, and, consequently, to each estimated location and orientation.

Figure 1 Typical Frame from the Video



(a) **(b)**

Figure 2 Estimation of Camera Orientation and of Airplane Location and Orientation
(a) Camera Orientation Estimation - Airplane Reference Points Aligned with Image
(b) Airplane Location and Orientation Estimation - Ground Reference Points Aligned with Image

With locations, orientations and timing known, it was possible to estimate the trajectory of the airplane. Velocities and rates of rotation could then be estimated by differentiating the trajectory data. High-order polynomial fits of locations and orientation angles were used to allow analytical differentiation. This avoided noisy velocity and rate estimates that would have been generated if the raw location and orientation data was differentiated.

Figure 3 shows speed, altitude and pitch angles over a 22.5 seconds long period beginning shortly after takeoff roll started and ending when the airplane was entering stall and the video no longer contained evidence that could be used for motion estimation. Rotation was approximately at time 12 seconds, as indicated by the increasing altitude in Figure 3.

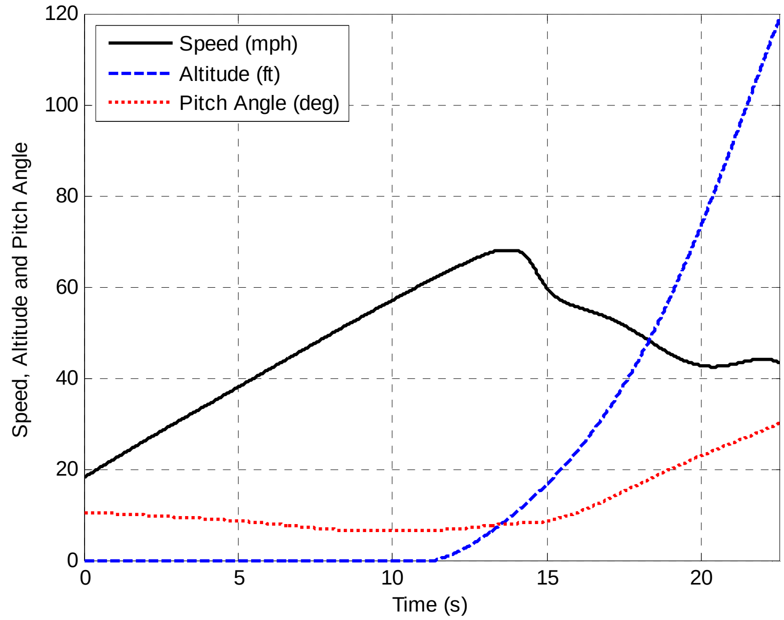


Figure 3 Estimated Speed, Altitude and Pitch Angle

The following figures show details of the flight starting at time 14 seconds, when the airplane was already airborne. Figure 4 shows the estimated flight speed. At time 14 seconds, the airplane was approximately 2 seconds past rotation and was airborne. The last shown time, 22.5 seconds, is when the camera orientation suddenly changed and neither ground nor tree tops could be seen in the video. The figure shows that speed started declining as soon as the airplane took off. At time 19 seconds, it was down to 45 mph and continued decreasing past that time.

Figure 5 shows the estimated angle of attack (assuming wind speed was negligible), pitch angle, and flight angle. Angle of attack reached 13.7º at time 22.5 seconds and continued increasing past that time. The decreasing speed and the increasing angle of attack indicate that the airplane was rapidly approaching stall. It was estimated that it reached speed and angle of attack corresponding to stall approximately 2 seconds after the last data points shown in Figures 3, 4, 5 and 6. The airplane impacted ground several seconds after that.

The estimated airplane altitude is shown in Figure 6. At time 22.5 seconds, it was approximately 120 feet. The maximum climb rate was reached at time 21.3 seconds and was estimated as 1090 ft/minute. The estimated roll angle up to time 22.5 seconds was within ±2º. After time 22.5 seconds, as the airplane was entering stall, it developed a large right-wing-down roll angle that could not be estimated because ground references were no longer visible in the video that was acquired through a window on the left side of the airplane. The airplane remained above the centerline of the runway throughout the 22.5 seconds long analyzed time period.

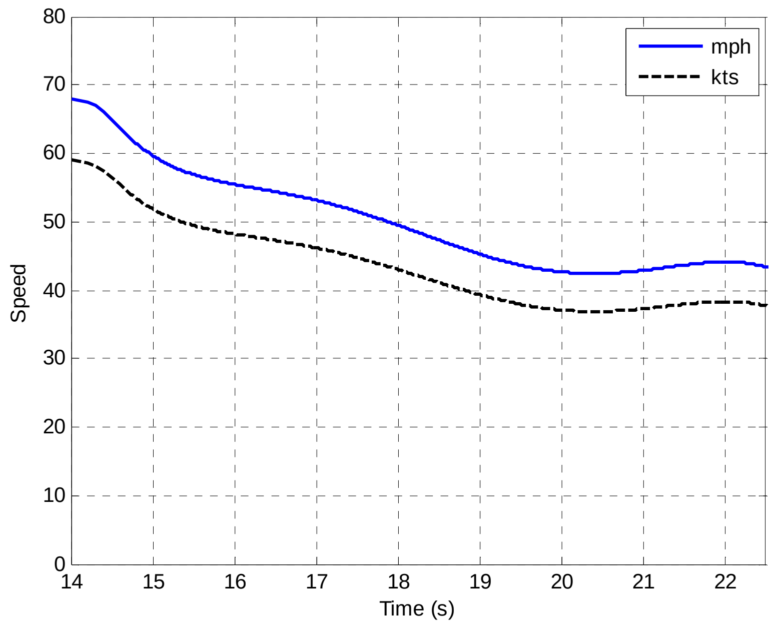


Figure 4 Estimated Flight Speed

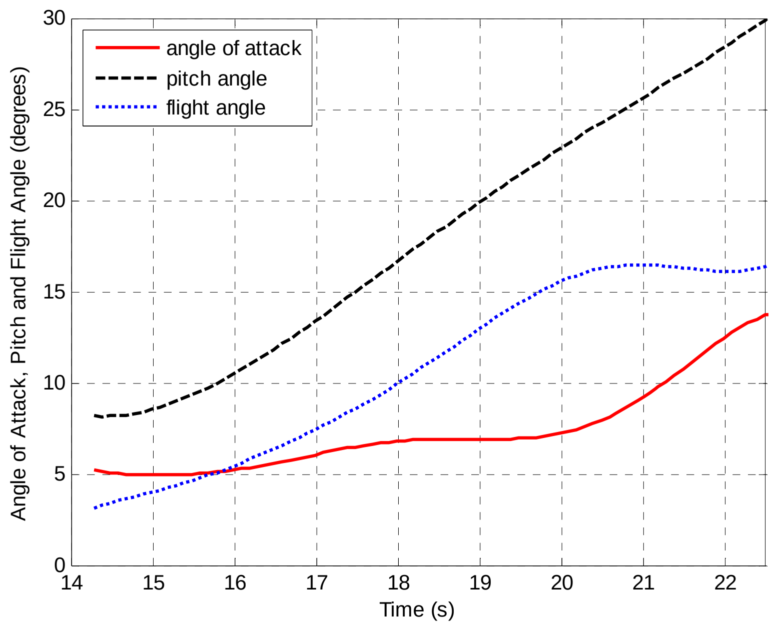


Figure 5 Estimated Angle of Attack, Pitch Angle, and Flight Angle

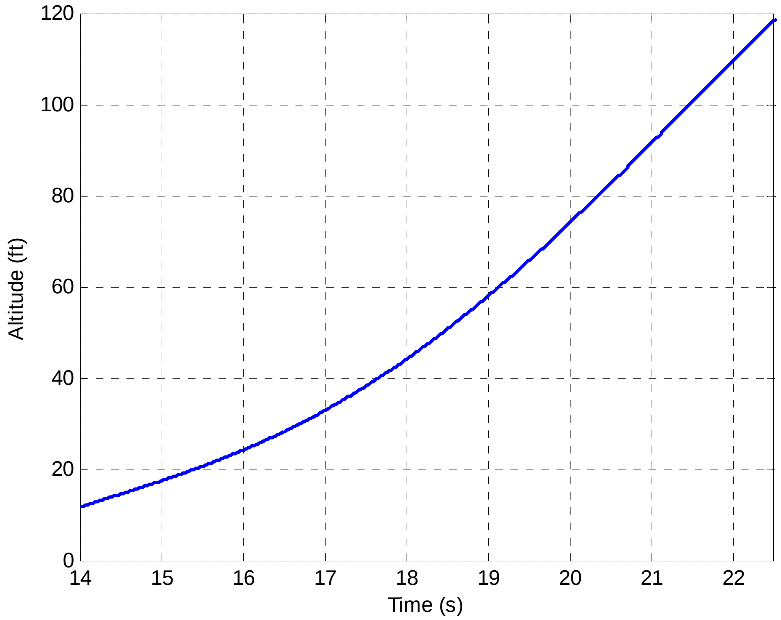


Figure 6 Estimated Altitude

E. CONCLUSIONS

Video acquired with an iPhone camera hand-held by a passenger in a DHC-3T airplane that crashed shortly after takeoff was used for estimating the trajectory and orientation of the airplane. That data was then used for estimating velocities, angular rates and angle of attack of the airplane.

The analysis revealed that shortly after takeoff, flight speed started decreasing rapidly and angle of attack started increasing rapidly. Approximately 11 seconds after takeoff, flight speed and angle of attack reached levels corresponding to stall. The airplane developed a large right-wing-down roll angle and impacted ground several seconds later.